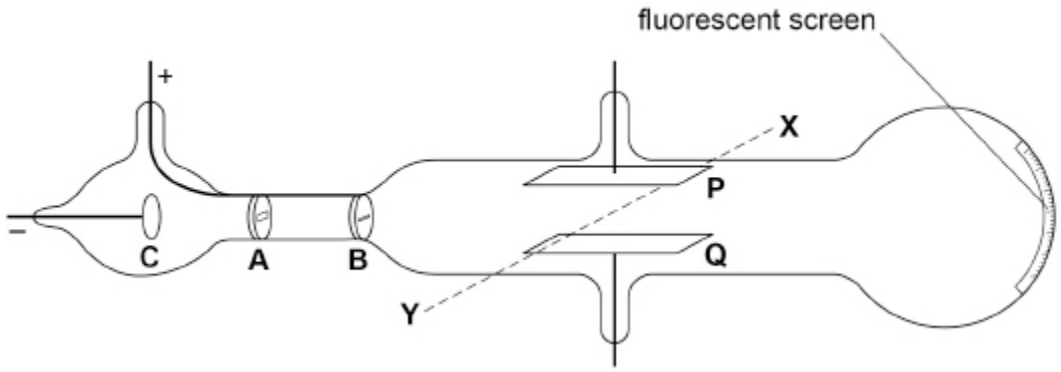
A-Level Physics

Cathode Rays

Question Paper

Time available: 68 minutes
Marks available: 38 marks

1. The figure shows a diagram of a discharge tube used by JJ Thomson to investigate cathode rays.



The direction **XY** is horizontal and at right angles to the axis of the tube.

(a) When correct connections are made to a high-voltage power supply, a cathode ray is produced. The cathode ray hits the centre of the fluorescent screen.

Describe how a cathode ray is produced in the discharge tube in the figure above.

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(2)

(b) **P** and **Q** are metal plates that can be attached to a second power supply.

In an experiment, a potential difference (pd) is applied across **P** and **Q** so that **P** is positively charged and **Q** is negatively charged. This deflects the cathode ray.

Then a magnetic field is applied between the plates so that the cathode ray follows its original path to the centre of the screen.

What is the direction of the magnetic field?
Tick (✓) **one** box.

from **P** to **Q** ☐

from **Q** to **P** ☐

from **X** to **Y** ☐

from **Y** to **X** ☐

(1)

(c) Changes are made to the apparatus so that the particles in the cathode ray travel with a greater speed as they pass between plates **P** and **Q**.

Explain how the cathode ray is restored to its original path by adjusting:

- only the electric field strength between **P** and **Q**
- only the magnetic flux density.

electric field strength only _____

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_____

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_____

magnetic flux density only _____

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(3)

(d) Using the apparatus in the figure above, Thomson determined the specific charge of the particles in the cathode rays. Thomson compared this result with the specific charge of the hydrogen ion.

Discuss the significance of Thomson's results for the particles in cathode rays, when compared with the specific charge of the hydrogen ion.

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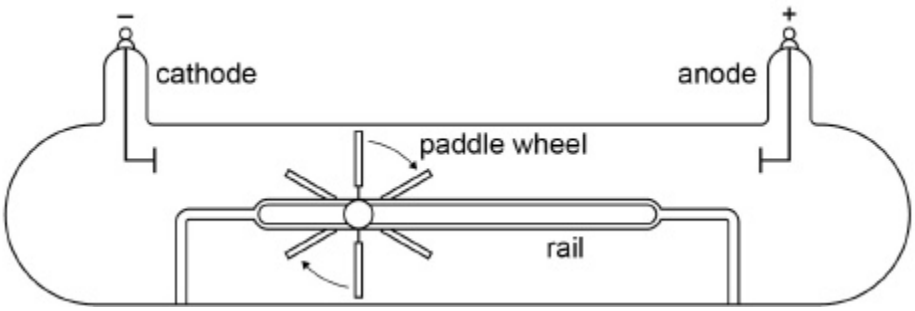
(2)

(Total 8 marks)

2. The diagram shows a gas discharge tube devised by William Crookes in one of his investigations.

When a large potential difference is applied between the cathode and anode the paddle wheel is seen to rotate and travel along the rail towards the anode.



(a) Explain how this experiment led Crookes to conclude that cathode rays are particles and that these particles caused the movement of the paddle.

(2)

(b) Later experiments showed that cathode rays are electrons in motion.

Explain how cathode rays are produced in a gas discharge tube.

(3)

(c) In a particular gas discharge tube, air molecules inside the tube are absorbed by the walls of the tube.

Suggest the effect that this absorption may have on the motion of the paddle wheel.

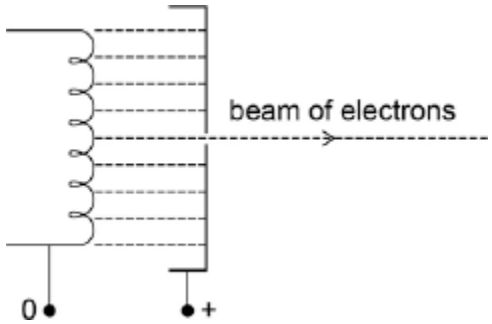
Give a reason for your answer.

(2)

(Total 7 marks)

3. **Figure 1** shows a narrow beam of electrons produced by attracting the electrons emitted from a filament wire, to a positively charged metal plate which has a small hole in it.

Figure 1



(a) Explain why an electric current through the filament wire causes the wire to emit electrons.

(2)

(b) Explain why the filament wire and the metal plates must be in an evacuated tube.

(1)

(c) The potential difference between the filament wire and the metal plate is 4800 V.

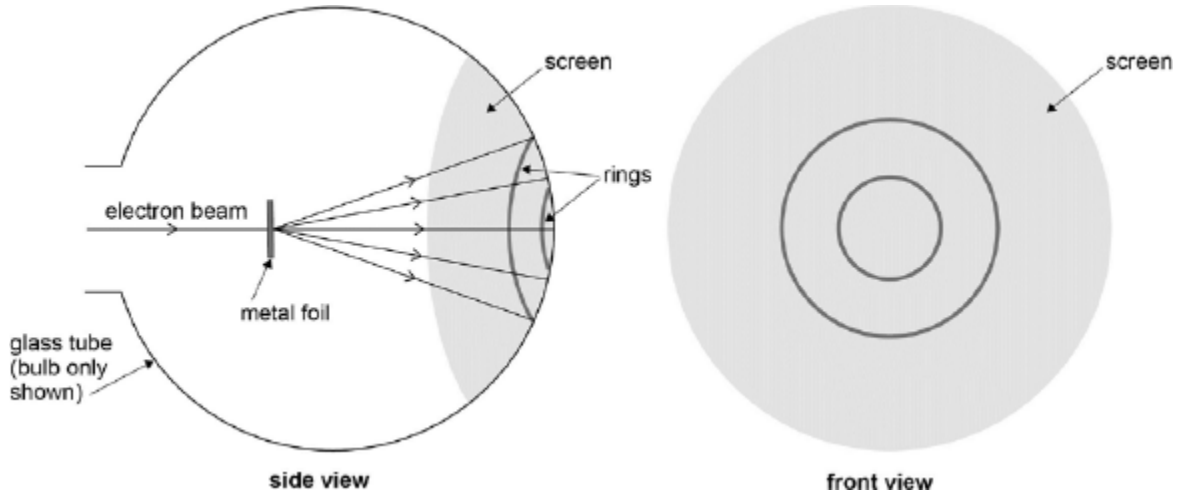
Calculate the de Broglie wavelength of the electrons in the beam.

wavelength = _____ m

(4)

The beam is directed at a thin metal foil between the metal plate and a fluorescent screen at the end of the tube, as shown in **Figure 2**.
The electrons that pass through the metal foil cause a pattern of concentric rings on the screen.

Figure 2



(d) The potential difference between the filament and the metal plate is increased. State and explain the effect this has on the diameter of the rings.

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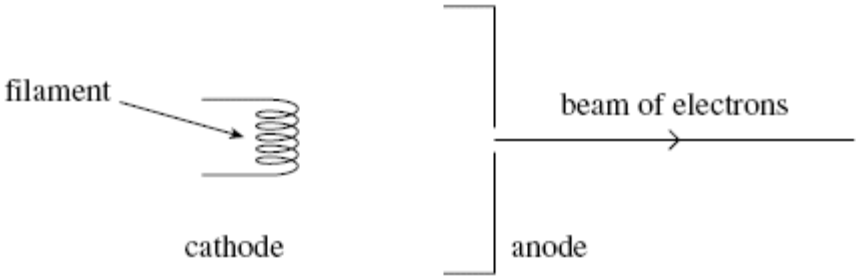
(3)

(Total 10 marks)

4. A narrow beam of electrons is produced in a vacuum tube using an electron gun, part of which is shown in **Figure 1**.

Figure 1



(a) (i) State and explain the effect on the beam of electrons of increasing the filament current.

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(2)

(ii) State and explain the effect on the beam of electrons of increasing the anode potential.

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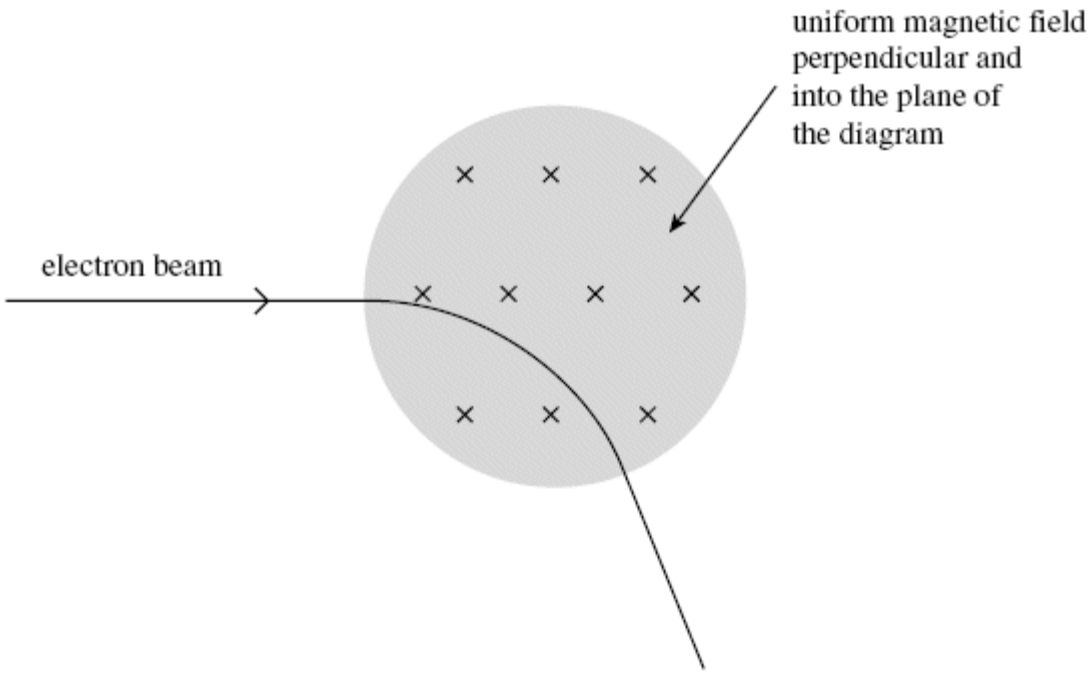
(2)

(b) The beam of electrons is directed at right angles into a uniform magnetic field as shown in **Figure 2**.

Figure 2



(i) Explain why the electrons move in a circular path at a constant speed in the magnetic field.

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(3)

(ii) When the speed of the electrons in the beam is 7.4×10^6 m s^{-1} and the magnetic flux density is 0.60 m T, the radius of curvature of the beam is 68 mm.

Use these data to calculate the specific charge of the electron, stating an appropriate unit. Give your answer to an appropriate number of significant figures.

answer = _____

(4)

(iii) Discuss the historical relevance of the value of the specific charge of the electron compared with the specific charge of the H^+ ion.

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(2)

(Total 13 marks)